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ANALYZING UNCERTAINTY IMPACT OF SATURATED PRESSURE AND CHAMBER PRESSURE IN CASE OF HUMIDITY GENERATION USING TWO PRESSURE TECHNIQUE

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ABSTRACT

The measured value given by any scientific measuring instruments is subject to some kind of errors. However, the reliability is assessed by the amount of error in the true value given by the instrument. Hence, it is necessary to identify the sources of errors and attempt shall be made to rectify them. As the true value of any measure may be function of several independent factors, therefore the impact of each independent factor, one by one, shall be examined on the true value keeping remaining factors constant.

Keywords: *Chamber Pressure, Humidity Generation, Pressure Technique, Independent Factors, Saturator.*

Introduction

Background of the Study

The model for generating relative humidity using two pressures, at National Physical Lab where the experiment was conducted, was connected with required devices and equipment for conducting the study. The gas is passed through regulators and flow control valve. Flowmeter has been used to monitor the flow rate. The gas was passed through a heat exchanger known as saturator. The saturation pressure Ps and saturation temperature Ts of the gas were measured at the point of final solution before gas leaves the heat exchanger. Then the gas passes through expansion devices where it was expanded to a lower pressure in desired test chamber. The final pressure Pc and temperature Tc of the gas were measured with the test chamber. From the test chamber the gas is exhausted to the atmosphere at an ambient pressure. For measuring pressure & temperature of the gas in the saturator and test chamber, precise pressure and temperature transduces were used. The humidity at chamber pressure, when the temperature of the gas is held constant during pressure reduction, may then be approximated as the ratio of the two absolute pressure and the relationship is given in equation (1), below:

$$\%R.H. = [[P_c/P_s] \times 100 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

P_c = the absolute pressure in the chamber

P_s = the absolute pressure in the saturator

Under the dynamic conditions where some slight temperature difference exist, the relative humidity formula for ideal gas may then be expressed in the form of equation (2)

$$\%R.H. = [e_w(T_s)/ e_w(T_C)] \times [P_c/P_s] \times 100 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where

$e_w(T_s)$ = Saturation vapour pressure at saturation temperature Ts

$e_w(T_c)$ = Saturation vapour pressure at saturation temperature Tc

P_c = the absolute pressure in the chamber

P_s = the absolute pressure in the saturator

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As can be observed from equation, relative humidity is a function of temperature, chamber pressure and saturator pressure. This implies that error in the true value of relative humidity is dependent on uncertainty of saturator pressure and chamber pressure.

Objective of the Study

The present study aims to examine the amount of uncertainty caused in the value of Relative Humidity generated using Two Pressure technique due to saturation pressure and chamber pressure. Their contribution towards uncertainty in the measurement of relative humidity generation has been examined.

Experimental Set Up

The effect of uncertainty due to saturation pressure in the calculation of RH was analyzed by calculating uncertainty component of saturation pressure under six different situations. The schematic diagram of the experimental set up is shown in Figure 1.

SCHEMATIC DIAGRAM OF THE EXPERIMENTAL SET UP

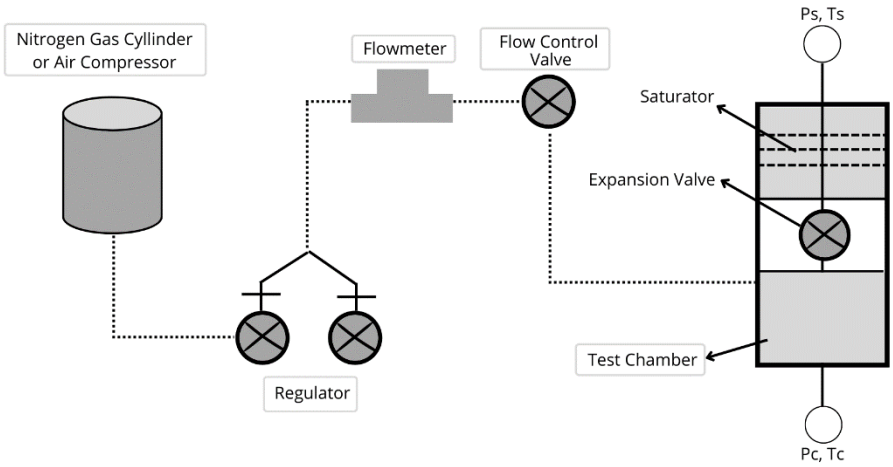
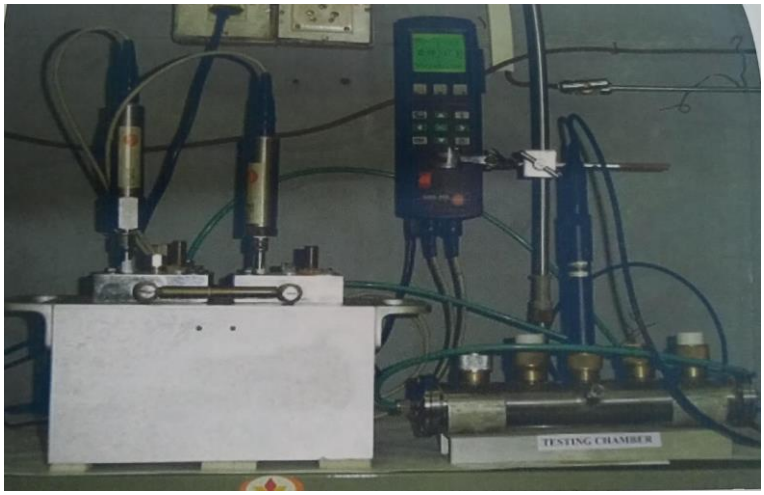


Figure 1

The actual photograph of the experimental set up at National Physical Laboratory is shown below:



The parameters namely temperature, chamber pressure and relative humidity were kept constant and different values of saturation pressure were taken. Thus, finally we had obtained different values of saturation pressure at which relative humidity alongwith other parameter was observed to have same value. In order to ascertain the uncertainty component of type B, following methodology was applied.

Step I: For a given set of values of relative humidity, temperature and chamber pressure, different values of saturation pressure were observed and their mean was calculated.

Mean saturation Pressure = Σ Ps /n = Avg Ps

Step II: Deviations from the mean value of saturation pressure were calculated and finally their squares were calculated.

Standard deviation s (RH) = $[(Ps - Avg Ps)/(n-1)]^{1/2}$

Step III: Using the sum of squares of deviation, uncertainty of type B was calculated using the formula given below:

Standard Uncertainty = $[s (Ps)/n]^{1/2}$

The uncertainty component of saturation pressure as well as chamber pressure under different situations were calculated and their effect on the calculation of relative humidity was analyzed by incorporating their effect in the actual values of saturation pressure and chamber pressure separately. The methodology of computing uncertainty in Relative humidity after adjusting for uncertainty in Saturated Pressure and Chamber Pressure, for one situation, is shown in table 1 and table 2 respectively. Ten different observations were taken for different values of saturated pressure as well as for chamber pressure and after including uncertainty factor in saturated pressure and chamber pressure separately, the corresponding level of Relative humidity was calculated. Using the values of Relative humidity, so obtained, uncertainty in Relative humidity was calculated as shown in the table 1 and 2.

Table 1: Calculation of Uncertainty in RH based on Uncertainty in Saturated Pressure

S,No.	Actual Ps	Actual Ps (Including Uncertainty)	Temp	Actual Chamber Pressure	Relative Humidity (Calculated)	Deviation form Mean	Deviation
1	5.00	5.01	22.10	1.03	20.58	0.05	0.00
2	5.04	5.05	22.10	1.03	20.42	-0.11	0.01
3	5.02	5.03	22.10	1.03	20.50	-0.03	0.00
4	5.03	5.04	22.10	1.03	20.46	-0.07	0.00
5	5.01	5.02	22.10	1.03	20.54	0.01	0.00
6	5.02	5.03	22.10	1.03	20.50	-0.03	0.00
7	4.99	5.00	22.10	1.03	20.62	0.09	0.01
8	4.98	4.99	22.10	1.03	20.66	0.13	0.02
9	5.02	5.03	22.10	1.03	20.50	-0.03	0.00
10	5.01	5.02	22.10	1.03	20.54	0.01	0.00
				Total	205.32		0.05
				Mean	20.50		0.01
						Std Uncertainty R(h)	0.02

Table 2: Calculation of Uncertainty in RH based on Uncertainty in Chamber Pressure

S. No.	Actual Pc	Actual Pc (Including Uncertainty)	Temp	Actual Chamber Pressure	Relative Humidity (Calculated)	Deviation Form Mean	Deviation
1	0.99	1.00	23.90	1.54	64.72	0.07	0.00
2	0.98	0.99	23.90	1.54	64.07	-0.58	0.34
3	1.00	1.01	23.90	1.54	65.37	0.72	0.51
4	0.98	0.99	23.90	1.54	64.07	-0.58	0.34
5	0.99	1.00	23.90	1.54	64.72	0.07	0.00
6	1.01	1.02	23.90	1.54	66.02	1.37	1.87
7	1.00	1.01	23.90	1.54	65.37	0.72	0.51
8	0.99	1.00	23.90	1.54	64.72	0.07	0.00
9	0.98	0.99	23.90	1.54	64.07	-0.58	0.34
10	0.97	0.98	23.90	1.54	63.42	-1.23	1.51
				Total	646.55		5.43
				Mean	20.50		0.01
						Std Uncertainty R(h)	0.25

*Pressure measured in terms of bar.

* Temperature measured in degree centigrade.

The calculated figures showing effect of uncertainty component of chamber pressure is summarized below in table 3.

Table 3

S.No.	Uncertainty Due to Chamber Pressure (a)	Uncertainty in Calculation of Rh (b)	Ratio of Uncertainty in Rh/Uncertainty in Chamber Pressure
1	0.0062	0.25	40.32
2	0.0042	0.07	16.66
3	0.0037	0.16	43.24
4	0.0037	0.12	32.43
5	0.0028	0.11	39.28
6	0.0042	0.12	28.57

The calculated figures showing effect of uncertainty component of saturation pressure is summarized below in table 4.

Table 4

S.No.	Uncertainty Due to Saturated Pressure (a)	Uncertainty in Calculation of Rh (b)	Ratio of Uncertainty in Rh/Uncertainty in Chamber Pressure
1	0.0065	0.02	3.076923
2	0.006	0.01	1.666667
3	0.0067	0.01	1.492537
4	0.0065	0.01	1.538462
5	0.0064	0.03	4.6875
6	0.0065	0.03	4.615385

Result Analysis

As can be observed from the results obtained in table 3 and 4, for a given change in uncertainty level of chamber pressure, there in higher corresponding change in Uncertainty of relative humidity in comparison to change in uncertainty of saturated pressure. It was further observed that as the uncertainty values of chamber pressure as well as saturated pressure, there is corresponding increase in uncertainty value of Relative humidity. There have been situations when for a given level of uncertainty in chamber pressure, different level of uncertainty has been observed in calculation of Relative humidity. This might have occurred due to other external factors.

Conclusion

The proportion of uncertainty in the calculation of RH due to uncertainty in chamber pressure is higher than uncertainty in saturation pressure. Thus, uncertainty in the calculation of RH will have higher value if there is any uncertainty in the calculation of chamber pressure. In order words, one should ensure higher accuracy in maintaining and calculating chamber pressure as any uncertainty in its calculation contributes significant amount of uncertainty in the calculation of RH. In case of humidity generation using two pressure technique, the preciseness of chamber pressure is more important than saturated pressure as error in it could lead to higher type B error in relative humidity generated using two pressure technique.

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